Chapter 4

ALOHA And SPADE

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Pure
ALLOHA

Pure ALAHA

- **1971, University of Hawaii began operation of ALOHA**
- **Satellite was used to interconnect university computers by use of a**
- **Random access protocol.**

Pure ALOHA Modes

- **Transmission mode:**
  - Users transmit at any time they desire,
  - Encoding transmissions with error detection code.
- **Listening mode: After Message Transmission**
  - User listens for (**ACK**) from the receiver.
  - If message collides (time overlap) receives (**NAK**)
- **Retransmission mode:**
  - When **NAK** is received, the message are simply retransmitted after a random time.
- **Timeout mode:**
  - IF, user does not receive either **ACK** or **NAK** within specified time, user retransmits message.

Successful & Total Traffic

- Total traffic arrival rate λ_t equals the acceptance rate λ plus rejection rate λ_r

$$\lambda_t = \lambda + \lambda_r$$

- If average length of packet is *b* bits.
- So, the average amount of **successful traffic (throughput)** is given by:

$$\rho = b\,\lambda$$

- Whereas the **total traffic** being:

$$G = b\,\lambda_t$$

Normalized Throughput and Normalized Total Traffic

- Assume channel capacity (maximum bit rate is given by *R* bps)
- So, normalized total traffic will be:

$$G_n = \frac{b\,\lambda_t}{R}$$

- Whereas, normalized throughput is:

$$\rho_n = \frac{b\,\lambda}{R}$$

Normalized Throughput and Normalized Total Traffic

- **If transmission time of each packet τ :**

$$\tau = \frac{b}{R} \quad i.e. \frac{b}{b/s} = s$$

- **Normalized throughput becomes:**

$$\rho_n = \tau\,\lambda$$

- **Normalized total traffic becomes:**

$$G_n = \tau\,\lambda_t$$

Poisson Process

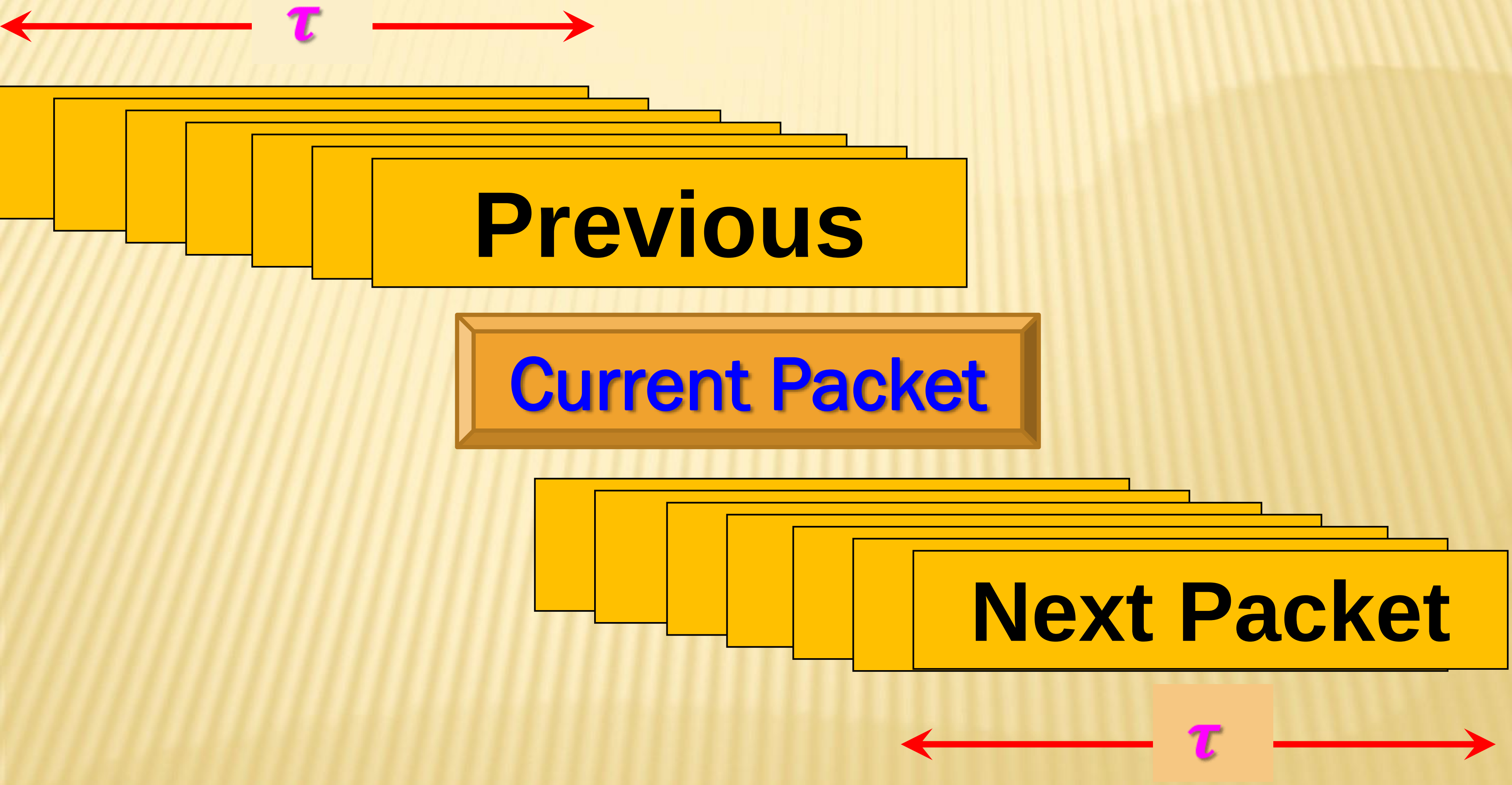
- The arrival statistics is often modeled as a **Poisson** process.
- So, the probability of K new messages arrive during a time interval τ sec is given as:

$$P(K) = \frac{(\lambda\tau)^K e^{-\lambda\tau}}{K!} \quad , \qquad K \geq 0$$

Collision Space

- If a user began message within previous τ sec, its tail end will collide with current packet.
- If another user begins a message within next τ sec, it will collide with the tail end of current packet.
- For no collision, a space of 2τ is needed.
- So, the probability of a user message is successful P_s is the probability when a 0 packets (K=0) are transmitted during a time interval 2τ (Probability of no transmission)

COLLISION INTERVAL



Probability of Success

- Putting $\tau = 2\tau,\ \lambda = \lambda_t$ and $K = 0$ gives:

$$P_s = P(K = 0) = \frac{(\lambda_t 2\tau)^0 e^{-\lambda_t 2\tau}}{0!} = e^{-2\lambda_t \tau}$$

- Also, probability that a user message is successful is given by definition as:

$$P_s = \frac{\lambda}{\lambda_t}$$

- Equating the above expressions:

$$\frac{\lambda}{\lambda_t} = e^{-2\lambda_t \tau}$$

$$\therefore \lambda = \lambda_t e^{-2\lambda_t \tau}$$

Throughput of Pure ALOHA

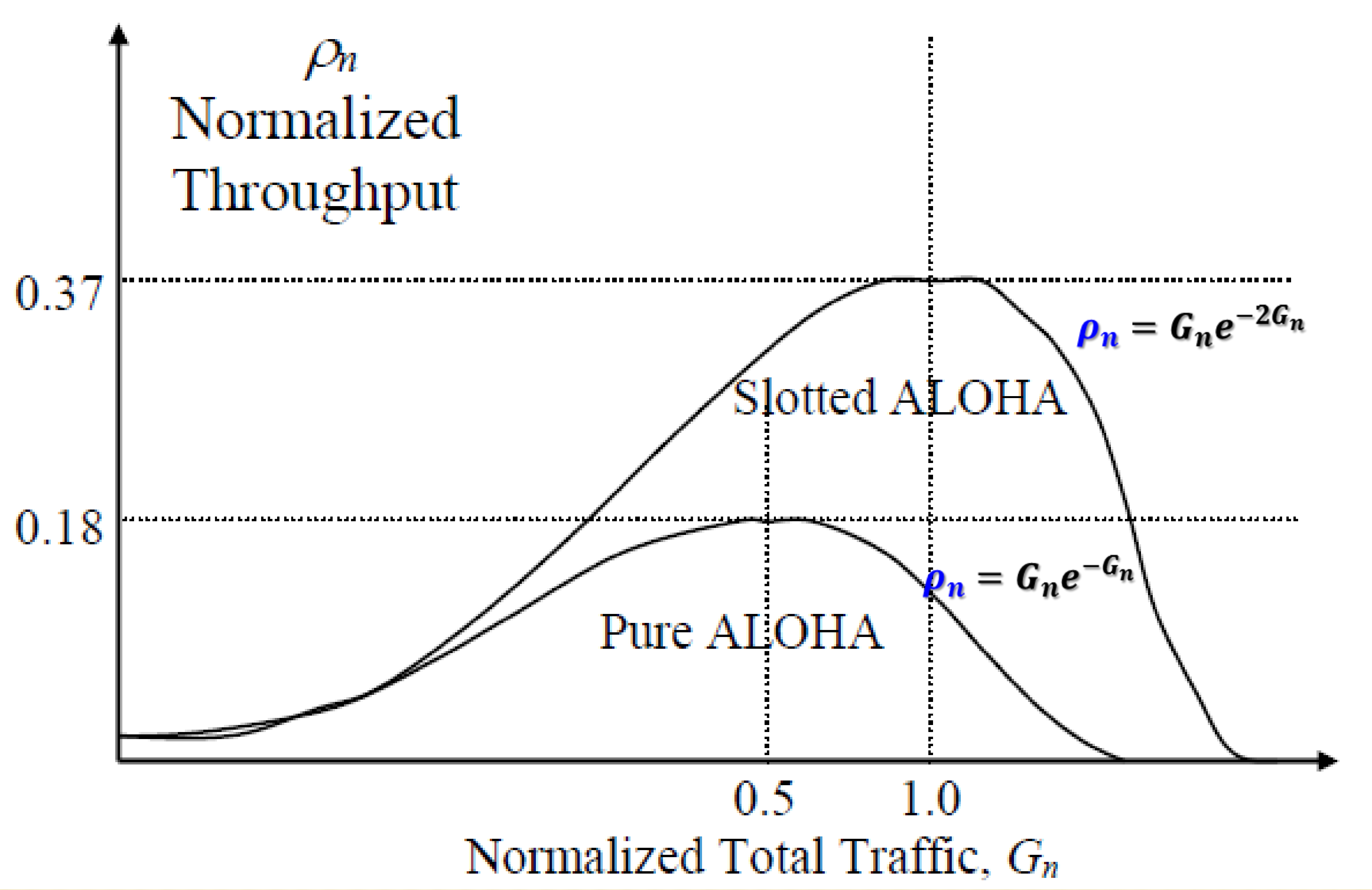
$$\therefore \lambda = \lambda_t e^{-2\lambda_t \tau}$$

$$\therefore \rho_n = \lambda\tau = \lambda_t \tau\, e^{-2\lambda_t \tau}$$

$$\therefore \rho_n = G_n e^{-2G_n}$$

- As G_n increases r_n increases til a point where further traffic increase creates a large collision rate to cause a reduction in the throughput.
- Maximum throughput 0.18 at G_n= 0.5.
- In pure ALOHA, 18% of communication resources can be only utilized.

Normalized Throughput



Slotted ALLOHA

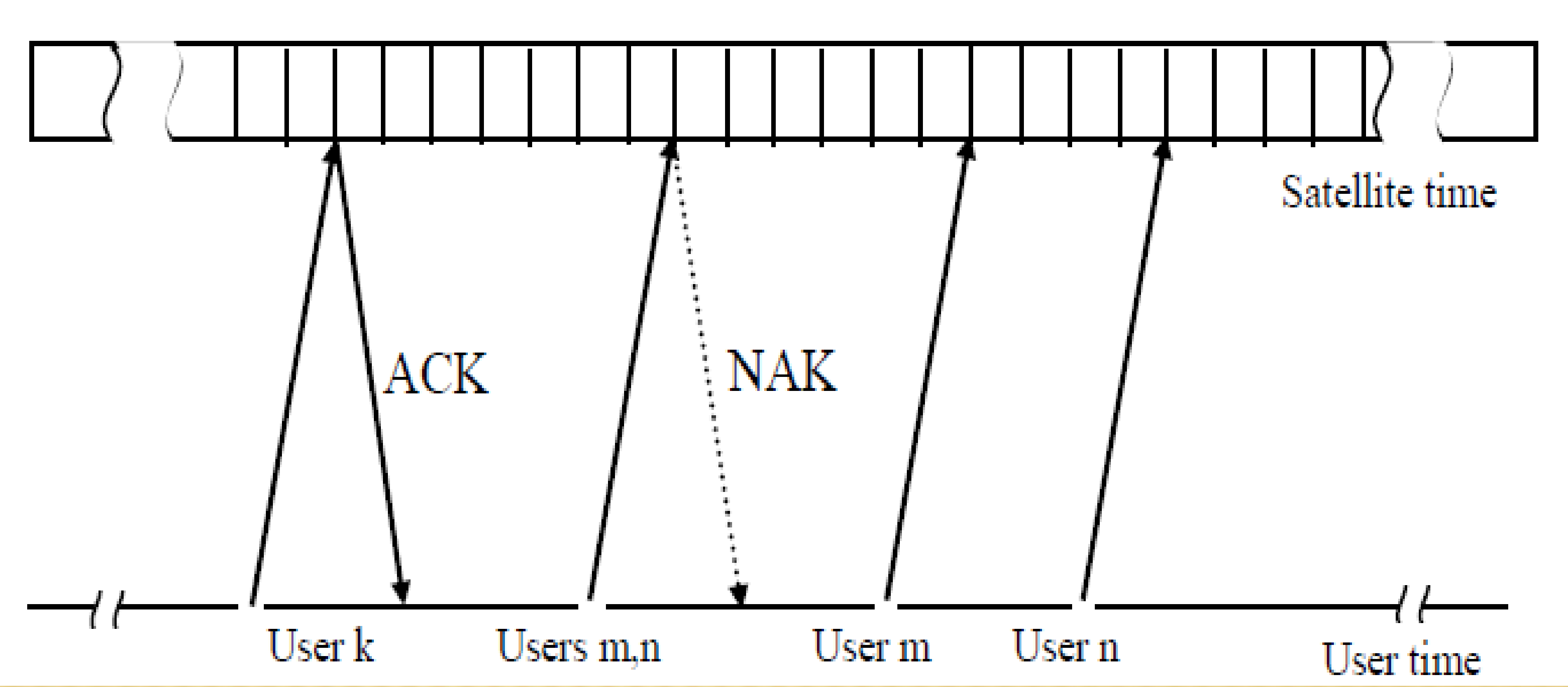
Slotted ALOHA

- **Pure ALOHA can be improved by making a small of coordination among stations.**
- **So, a sequence of synchronization pulses is broadcast to all stations. Messages are required to be sent in the slot time between synchronization pulses, and can be started only at the beginning of a time slot.**
- **This reduces rate of collisions by half, since only messages transmitted in same slot can interfere with one another. The reduction in the collision window from 2τ to τ results in:**

$$\rho_n = G_n e^{-G_n}$$

Throughput of Slotted ALOHA

- Maximum throughput is 0.37%.
- if a negative NAK is received, user retransmits after a random delay of integer no of slot times.



Reservation
ALLOHA

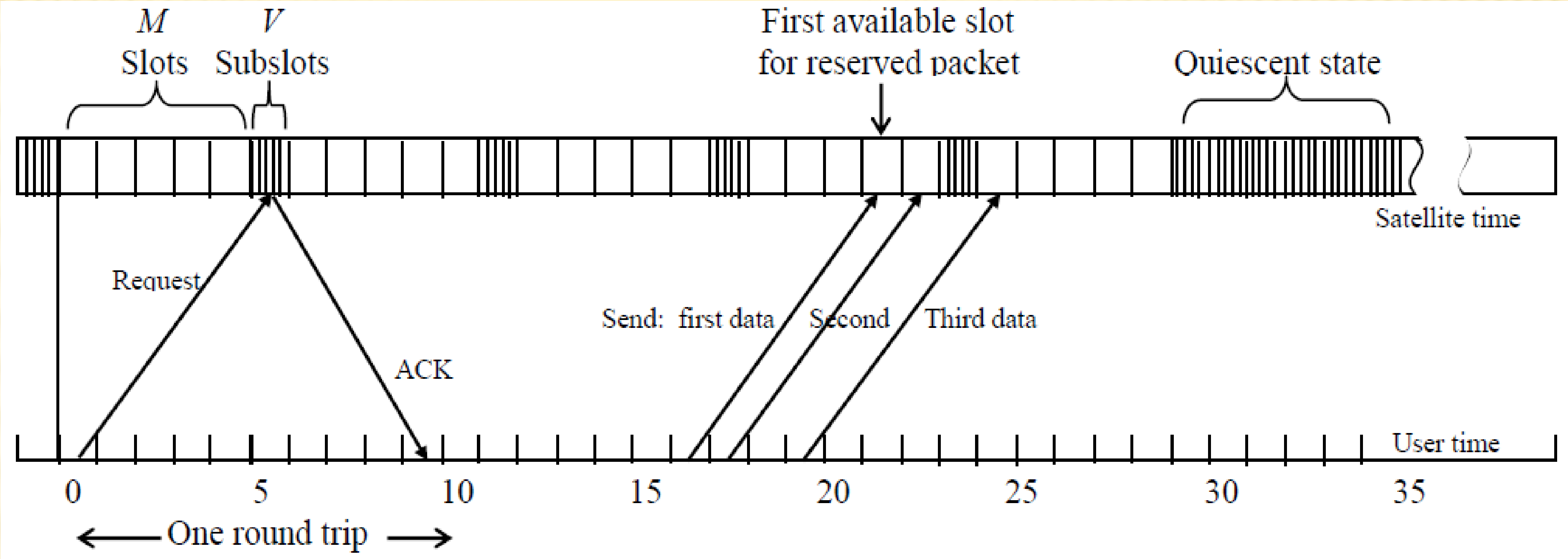
Unreserved Mode

(Quiescent State)

When no reservations taking place, system waits for requests of reservation:

- **Frame time is divided into a small reservation sub-slots.**
- **Users use sub-slots to reserve message slots.**
- **After requesting, the user listens for an ACK and a slot assignment.**

Reservation ALOHA



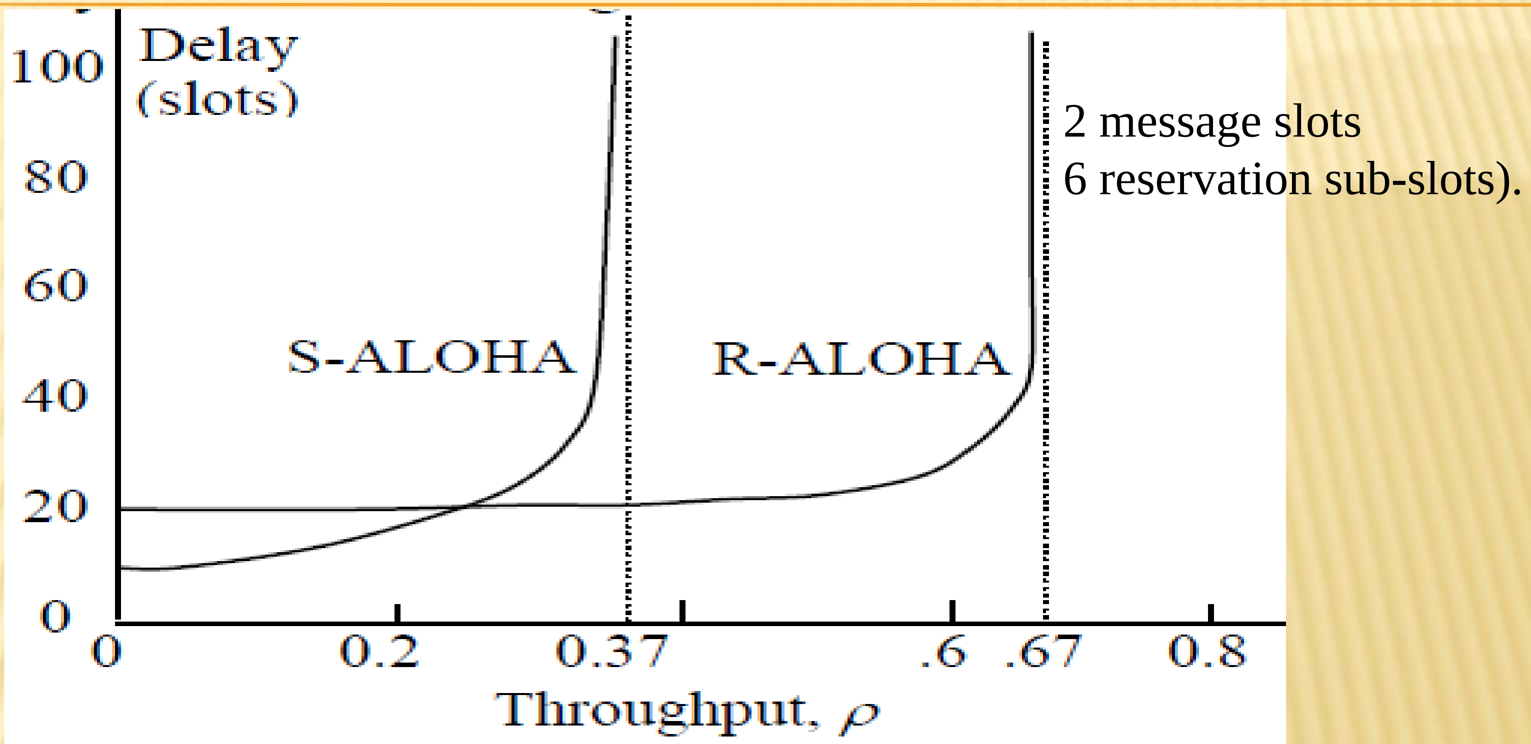
- 6 slots per frame, each can be divided into 6 sub-slots.
- In quiescent state (no reservation) time is partitioned into short 6 x 6 = 36 sub-slots.
- Once reservation is made, system is reconfigured into M=5 message slots followed by only 6 sub-slots for reservation.

Reserved Mode

Once reservation is made, the system is reconfigured as follows:

- The time frame is divided into $M+1$ slots.
  - First M slots are used for message transmissions.
  - Last slot is subdivided into sub-slots to be used for reservation/requests.
- Users sent message packets only in their assigned portions of the M slots.

Slotted and Reservation



- **At low values ρ<0.2, R-ALOHA pays the price of greater delay due to the greater overhead.**
- **For ρ > 0.2, collisions and retransmission of S-ALOHA cause a more quick delay increase.**
- **At higher throughput (ideal case 0.37 for S-ALOHA and 0.67 for R-ALOHA) the delay is unbounded.**

SPADE

Definition of SPADE

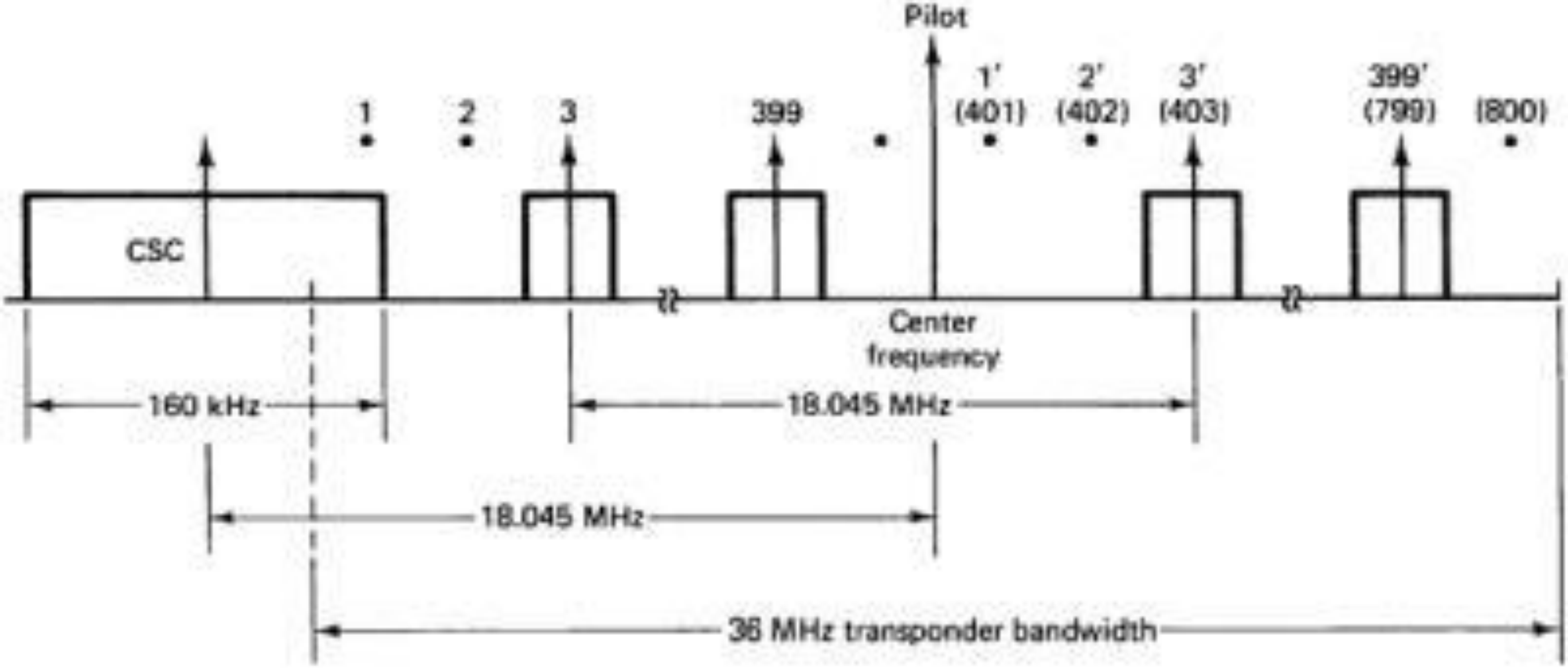
- SPADE stands for Single-channel-per-carrier PCM multiple Access Demand assignment Equipment.
- SPADE is a DAMA system where all channels are shared and are allocated to users as needed
- It is a flexible method to serve many light traffic links and is an efficient way to handle overflow traffic from medium-capacity preassigned links.
- A SPADE transponder with 800 channels is equivalent to 3200 MCPC channels.

The Principle Features

- A single voice-grade channel is A/D converted at a bit rate of 64 kbps.
- This signal modulates a carrier using QPSK (only one voice channel per carrier).
- The channel spacing is 45 kHz so that there are 800 channel carriers per transponder 6 of them are vacant (i.e., 794 FDMA channel carriers).
- Carrier is dynamically assigned, upon demand.
- Dynamic assignment is accomplished over a 160 kHz common signaling channel (CSC) with a bit rate 128 kbps and BPSK.

FREQUENCY ALLOCATIONS OF SPADE

- To avoid interference with CSC, channels 1 and 2 are left vacant, and 401 and 402 to maintain duplex matching.
- Channel 400 also must be left vacant and its duplex 800.



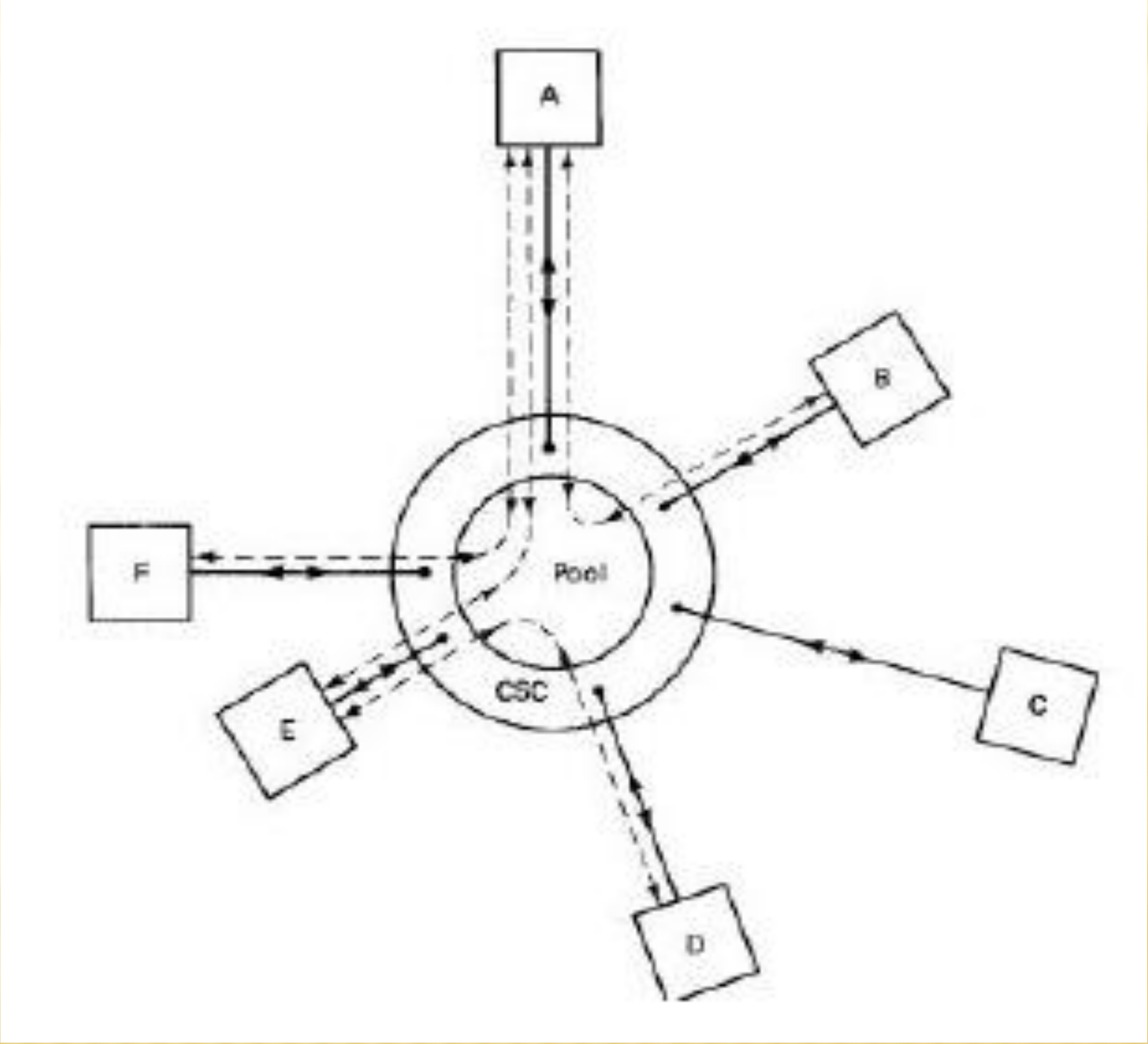
CSC Operation

- CSC operates in a fixed-assignment TDMA broadcast mode; all earth stations monitor it.
- Each earth station has 1-ms time slot every 50 ms for requesting or releasing a channel.
- If an earth station needs a channel, it seizes a free one and transmits its selection on CSC.
- As soon as the channel is allocated, idle-channel list is updated via CSC so that other stations processors delete it from their list.
- If station finches with channel, it indicates the channel's release by transmitting a signal in its time slot on CSC. Other stations receive this signal.
- If two earth stations simultaneously seize same channel, they each get a busy signal. They try again at random from the pool of available channels.

SPADE Operation

- All earth stations are permanently connected through the CSC.
- Each earth station has the facility for generating any one of the 794 carrier frequencies using frequency synthesizers.
- It has a memory containing a list of the frequencies currently available, continuously updated through CSC.

C Wants to Call F



C Wants to Call F

- Suppose a call to station F is initiated from station C.
- C will first select a frequency pair at random from those currently available on list and signal this information to station F via CSC.
- Station F must acknowledge, through CSC, that it can complete the circuit.
- Once circuit is established, other stations are instructed, through CSC, to remove this frequency pair from list.
- Once call has been completed and circuit disconnected, the two frequencies are returned to pool, information again being transmitted through CSC to all earth stations.
- Cities chosen at station C may be assigned to another circuit. In this event, station C will receive the information on CSC update and will immediately choose another pair at random, even before hearing back from station F.

Signaling Information

- As well as establishing connection via satellite, CSC passes signaling information from calling station to destination station.
- In the example above from station C to station F. Signaling information in SPADE is routed through CSC rather than being sent over voice channel.
- Each earth station has demand assignment signaling and switching (DASS) unit which performs the functions required by CSC.
- Time division multiple access is used for this purpose, allowing up to 49 earth stations to access the common signaling channel.

Polling Techniques

Polling Techniques

- To institute a controller that periodically pools user population to determine their request.
- A technique for rapidly polling user population is called binary tree search to resolve contention among users.
- Time saving is possible for large population and small service demand.
- No of decisions with a binary tree search for a population Q is:

$$n = \log_2 Q$$

Procedure

- Assume terminals 001, 100, and 110 contending for service of a single channel.
- Satellite request the first bit of identification from the contending terminals.
- Terminal 001 transmits 0 and terminals 100 and 110 each transmit 1.
- Satellite selects 1, based on received signal strength S/N, and informs all terminals, so half user population knows that it has not been selected. So, terminal 001 bows out.
- Satellite requests the second identifying bit from the remaining contending terminals.
- Terminal 100 transmits 0 and terminal 110 transmits 1.
- Assume the satellite selects 0; terminal 110 bows out so that terminal 100 is free to access satellite
- When channel becomes available above steps repeated

EXAMPLE OF POLLING PROCEDURE